Reply to Anonymous Referee #3

Thanks for the reviewer's helpful comments. We have given our point-to-point response to your comments in the revised manuscript.

General comments:

This paper investigated the role of warming Tibetan Plateau on winter air quality in the Sichuan Basin, China. This paper has indicated that the air temperature in winter over the TP has risen by 2 degrees from 2014 to 2017. Then the authors used sensitivity experiments to examine the influence of the waring TP on air quality in the Sichuan Basin. This paper is well written and well organized. However, this manuscript has not provided any physical explanations for the linkage between warming TP and less air quality in Sichuan Basin. In fact, I doubt that the relation between warming TP and less air pollution is not a cause-and-effect relation other than a companion relation caused by atmospheric circulation. Based on the following comments, I will not recommend publication for this manuscript at current situation. Of course, the resubmission is encouraged.

Major comments:

Comment 1. The description on the experiment design is too simple to be understood. How the authors set the temperature increment to 2 degrees? Only stations over the TP or all grids in the domain of the TP? please clarify this issue.

Response: We have added the detailed description of the 2°C increment settings. In the sensitivity simulation, we set the 2°C increment at all grids in the domain of the TP. The text is "*According to the meteorological records at weather stations, surface air temperature risen by an average of 2°C from 2013 to 2017 over the Tibetan Plateau (Table S1). ERA-interim reanalysis data also show that the troposphere (600hPa - 250hPa) over the plateau is warming during the 2013-2017 period, and the temperature increment shows a parabolic pattern with the altitude, by an average increase of ~2°C (Figure S1). Thus, we design a sensitivity simulation, with a temperature increase of 2°C in the troposphere over the plateau. In the model, we set to the 2°C warming at all grids covering the plateau (the region surrounded by the dark line in Figure 1b) in the initial and boundary fields. In order to ensure a persistent influence of the 2°C warming, we drive the initial field with a 2°C increment every day. Then, by comparing the difference between the sensitivity simulation and the baseline simulation, we determine the impact of the 2°C warming over the Tibetan Plateau on air quality in the Sichuan Basin.*" In Lines 167 - 178.

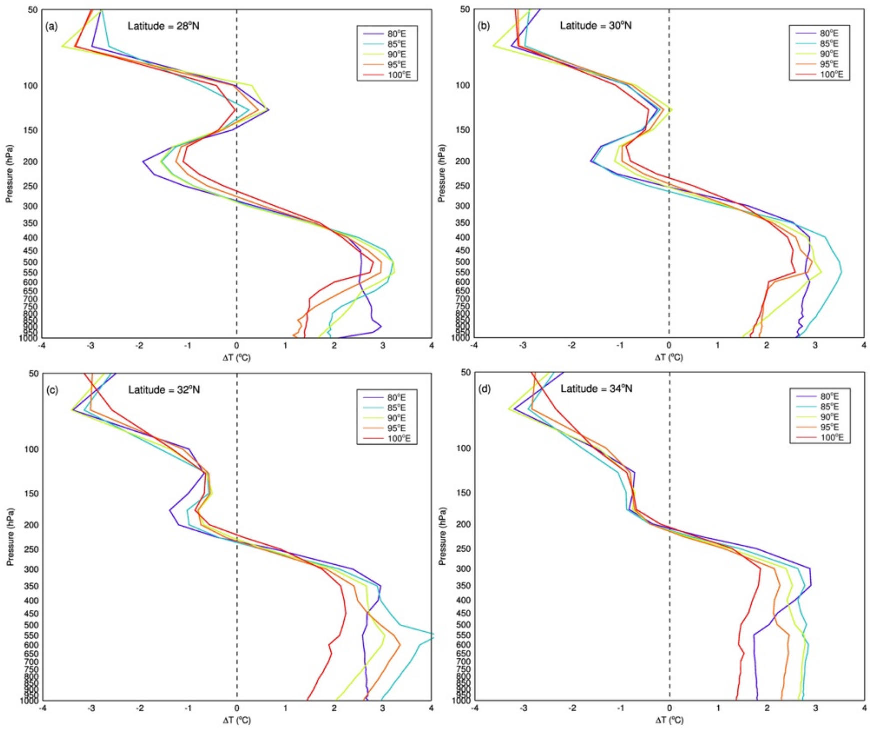

Figure S1 Vertical profile of temperature change along the longitude (80°E -100°E) covering the plateau at 28°N, 30°N, 32°N and 34°N, ΔT is calculated by the annual temperature increase rate from 2013 to 2017 multiplying by the number of years (N = 5). Noted that the temperature in the troposphere over the Tibetan Plateau (600 hPa - 250 hPa) is inhomogeneously warming by 0 - 4 °C from 2013 to 2017, and we take an average warming increase of 2 °C.

Comment 2. Please clarify the mechanism that the warming TP causes less air pollution in the Sichuan Basin. Please make sure whether the warming TP influence large-scale atmospheric circulation through air-land interaction? I think that the warming TP is a result other than a cause.

Response: We have added the analysis of pressure gradient to explain the mechanism between the warming TP and less air pollution in the Sichuan Basin (Figure 8, a new figure). In our study, we focus on how the warming TP affects air pollution via changing winds, temperature and the PBL height as well as RH in the Sichuan Basin.

The text is as follows: "*We further compare the difference in the surface pressure between the baseline and sensitivity simulations, and find out that surface pressure over the plateau and the basin all decreases when the plateau warms by 2°C (Figure 8a and 8b). Over the plateau, the pressure drop has a decrease characteristic from west to east (Figure 8c), which results in a decreased pressure gradient and a weakened westerly wind. While in the basin, the pressure drop is less than the plateau. This leads to an increased pressure gradient from the basin to* *the plateau, inducing an intensified easterly wind. The enhanced easterly wind causes an increased transport of $PM_{2.5}$ from the basin to the plateau. On the other hand, the weakened westerly wind and the enhanced easterly wind are convergent at the border between the plateau and the basin (Figure 7), jointly leading to an increase in $PM_{2.5}$ concentration at the eastern edge of the plateau."* in Lines 279 - 289.

"After the 2°C warming, surface pressure decreases in the basin (Figure 8), which produces more convergent airflow (as shown in Figure 7). The strengthened convergent airflow induces an intensified ascending motion, conducive to a reduction of temperature in the basin. As a result, the zone where the maximal temperature drop appears, overlaps with the zone with the maximal ascending motion. Furthermore, the intensified updraft increases the vertical temperature gradient and the instability in the lower troposphere of the basin, thereby causing a higher PBL height than that in the non-warming case (Figure 10b). On the contrary, the change in vertical temperature profile leads to a decreased vertical temperature gradient and increased thermal stability in the lower troposphere of the plateau, in which the PBL height decreases.

On the other hand, the convergent airflows by a weakened westerly wind over the plateau and a strengthened easterly wind in the basin (shown in Figure 8) triggers an ascending motion on the east side of the plateau, which is also beneficial to the development of the PBL height in the basin. Consequently, the elevated PBL facilitates vertical diffusion, leading to a reduction in $PM_{2.5}$ concentration over the basin." in Lines 318 - 332.

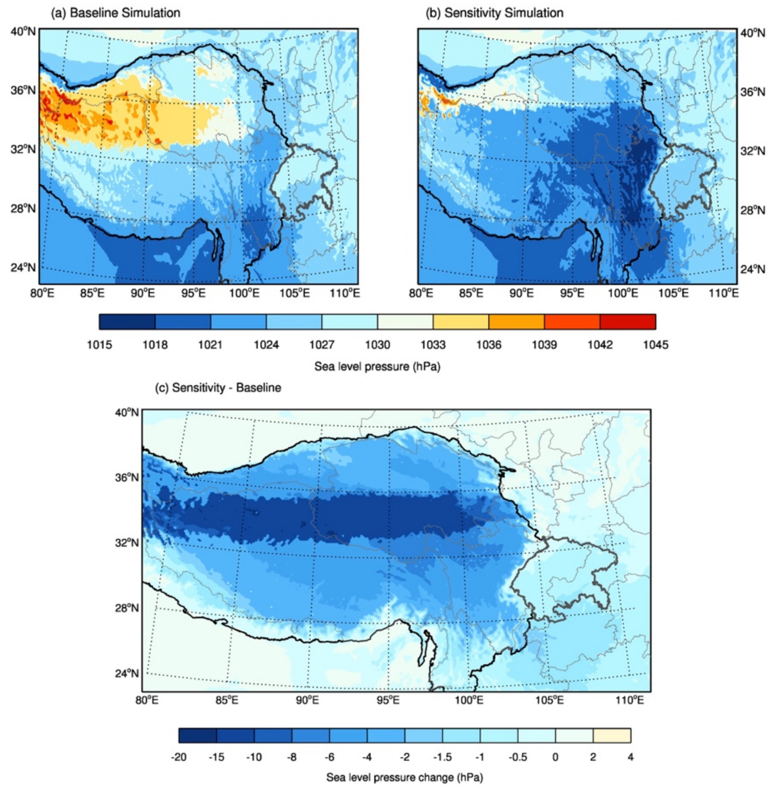

Figure 8 Comparison of spatial distributions of sea level pressure (SLP) between the (a) baseline simulation and (b) sensitivity simulation over the Tibetan Plateau and Sichuan Basin. (c) The SLPs over the plateau and basin decrease while the plateau becomes 2°C warming.

Comment 3. significance testing is important for your results. Please make some significance test for your results. For example, Fig. 5 and Fig. 6 show the difference between observations and simulations. Whether the difference between them is significant?

Response: Thanks for your suggestions, and we have added the Student's *t test* to validate the significant difference between observations and simulations in the revised manuscript. Results show that the difference is extremely significant, and here we have added the *p*-value ($p < 0.001$) in Figure 5, rather than the exact value, because the *p*-value ($p = 5.76E\text{-}19$) is far less than 0.001. The related text is "*The results show that $PM_{2.5}$ concentration in the basin is significantly reduced by an average of 25.1 μg m^{-3} in the case of 2°C warming, with a confidence level of 99.9% ($p < 0.001$).*"

Figure 6 calculates monthly-averaged concentrations of chemical composition in $PM_{2.5}$. To calculate the significance of every chemical composition, we use raw data in Figure 5, because $PM_{2.5}$ concentration is the sum of concentrations of SO_4^{2-}, NO_3^-, NH_4^+, Cl^-, SOA, POA, EC and Undef in Figure 6. Results show that differences in most of the chemical composition are extremely significant ($p < 0.001$) except that the EC is more significant ($0.001 < p = 0.0011 < 0.01$). The *p*-values of every chemical composition are summarized as Table S2 in Supplemental materials, not shown in Figure 6. The Table S2 and its related text is below: "*Significance testing of the difference in every chemical composition between the baseline and sensitivity simulations are also given in Table S2. The p-values of most chemical composition in $PM_{2.5}$ are far less than 0.001 except that the p-value of EC is 0.0011 (Table S2), implying for an extremely significant reduction of every chemical composition in $PM_{2.5}$ within the basin when the plateau warms by 2°C.*"

Table S2 *Significance differences in concentrations of chemical composition in $PM_{2.5}$ between the baseline simulation and sensitivity simulation. The p-value of every chemical composition is followed.*

Chemical composition	SO_4^{2-}	NO_3^-	NH_4^+	Cl^-	SOA	POA	EC	Undef
p-value	2.78E-04	5.05E-06	6.84E-05	3.29E-04	6E-130	2.14E-06	0.0011	2.63E-15

Minor comments:

Comment 4: Fig. 7, please indicate the information of winds.

Response: Added. *"On the other hand, the weakened westerly wind and the enhanced easterly wind are convergent at the border between the plateau and the basin (Figure 7), jointly leading to an increase in $PM_{2.5}$ concentration at the eastern edge of the plateau. Additionally, northerly winds over the basin slightly enhance, conducive to diluting the air and reducing $PM_{2.5}$ concentration."* In Lines 286 - 290.